8.10 HEPA FILTER VACUUM CLEANERS AND PORTABLE HEPA FILTRATION SYSTEMS

HEPA filtered vacuum cleaners (HEPA-Vacs) and Portable HEPA Filtration Systems (PHFS) are most commonly used to control friable particulate before it becomes airborne. They are also used to control airborne particles and liquids in and around work areas and to provide localized control of loose debris when work operations could potentially cause the spread of contamination. When used in the nuclear industry, the HEPA-Vacs are commonly referred to as nuclear or radiological vacuum cleaners.

8.10.1 DESCRIPTION OF RADIOLOGICAL VACUUM CLEANERS

Radiological vacuum cleaners are generally well-constructed and well-sealed devices with a HEPA filter on the exhaust. They are normally mounted on a cart with a comfortable handle and lockable and steerable wheels for portability and control during use. The power module consists of a blower powered by an electric motor and controlled by an onboard switch. The filter module consists of a positively mounted and sealed HEPA filter, protected by a prefilter. All units should have a positive plenum (tank)-to-vacuum head seal. Vacuums that have latches but provide a loose head-to-tank seal that depends on the vacuum force to provide a positive seal (i.e., many commercially available shop vacuums) should not be used.

Some vacuum cleaners are equipped with controllers that allow the worker to regulate the flow. This works well in providing negative ventilation in small glove bags. Using HEPA filtered vacuum cleaners can significantly improve how contamination is controlled.

An in-line HEPA filter can be installed in the suction hose to collect radioactive material before it reaches the vacuum cleaner. Fittings can be made to connect the vacuum cleaner hose to the HEPA filter. As debris is sucked into the hose, it is deposited on the in-line HEPA filter instead of the HEPA filter inside the vacuum cleaner. Temporary shielding should be installed around the in-line filter before operation, as the filter becomes highly radioactive.

If a large amount of debris will be collected, installation of a waste drum in the suction hose should be considered to ensure the debris collects in a waste drum and not the vacuum cleaner. Commercial systems are available, or one can be made by welding two pipes into a spare drum lid. As each drum is filled, the lid can be swapped to a new drum and a regular lid can be installed on the full drum. Personnel doses are reduced because the debris is collected directly into the waste drum instead of the vacuum cleaner.

Vacuum cleaners should be constructed of a material that is easily decontaminated without damage to components. Units that use silicone-based material to prevent leakage should not be used. All hose connections should provide positive seals and should be constructed of a material that will not be damaged by repeated use or rough handling.

HEPA filters should have a positive seal and pass in-place leak testing. The filter hold-down clamps should provide the required force (20 lb/in.^{2}) to seal the filter and prevent dislodging during rough handling and repeated use. They should be constructed of a material that will not wrap or bend with repeated use.

The HEPA filter replacement method should be simple and should performable in minimum time to reduce exposure and the chance of radioactive contamination. The vacuum cleaners should be designed to ensure HEPA filter integrity under all conditions of use and to prevent unauthorized or accidental access to the inner surfaces of the vacuum. Units should be constructed with no sharp edges or burrs that could injure personnel or damage protective clothing.

HEPA filters used in HEPA-Vacs and PHFS should meet the efficiency and construction requirements for HEPA filters in DOE STD 3025[7] and ASME AG-1.[3] The maximum flow rate of the device should not exceed the flow rate at which the HEPA filter was efficiency tested. The HEPA filters should be certified at the ORFTF.

8.10.2 OPERATION

HEPA-Vacs and PHFS are used to clean up radioactive debris and provide negative ventilation in the work area. Improper use of HEPA-Vacs and PHFS may result in generation of airborne radioactivity, loose surface contamination, or high dose rates. HEPA-Vacs or PHFS used for radioactive material should be marked "For Radioactive Service Only."

A nuclear safety review must be performed and documented prior to use of a HEPA-Vac or PHFS for fissile material.

HEPA-Vacs or PHFS must be appropriate for the type and amount of radioactive material involved. The health physicist is responsible for determining the levels of filtration required on the exhaust. Programmatic organizations are responsible for the following:

- Maintaining control of HEPA-Vacs or PHFS.
- Ensuring that HEPA-Vacs or PHFS are tested annually. HEPA-Vacs or PHFS must be retested if the integrity of the filter media or the sealing surface of the HEPA filter is compromised, if the HEPA filter is exposed to water or high levels of water vapor, or if the HEPA filter is transported to another area or site.
- Ensuring that HEPA-Vacs or PHFS are properly labeled, controlled to avoid improper use, and serviced or emptied only by individuals trained to do so, and that the health physicist is contacted before they are opened.

HEPA-Vacs or PHFS used in contaminated areas should be equipped with HEPA-filtered exhausts or with exhausts that are directed to installed systems that are equipped with HEPA filters. Such provisions may not be necessary when these systems are used in areas where only tritium or radioactive noble gases are present or when the material to be vacuumed is wet enough to prevent the generation of airborne radioactive material or removable surface contamination. Extended use of air handling equipment may cause a significant buildup of radioactive material in the ductwork and filters. Periodic sampling of the exhausted air and surveys of the accessible surfaces of the equipment should be performed to assess the radiological impact of equipment operation. While use of the devices discussed above has been proven effective in reducing contamination spread and associated decontamination costs, these benefits must be weighed against the potential costs. Use of engineering controls may require expenditure of worker doses to set up, work in, maintain, and remove the device. There may be financial costs associated with device purchase or manufacture, worker training, possible reduced productivity, and device or component maintenance and disposal.

8.10.3 TESTING AND PERIODIC MAINTENANCE

Problems with operating HEPA-Vacs or PHFS are often not visually observable or detectable by onboard instrumentation. Therefore, filter replacement and testing are important to the continued safe operation of the unit. In-place testing is designed not only to validate the HEPA filter, but also to verify the integrity of associated seals, gasketing, ducting, and housings to leakage.

All HEPA filters used in the system should be tested by the DOE Test Facility at Oak Ridge National Laboratory before initial use. In addition, the device should be leak-tested prior to initial use when units have been opened, moved, or transported, as well as annually. Leak tests are conducted by injecting an aerosol challenge into the inlet of the device and measuring the aerosol challenge concentration at the inlet and outlet of the device.

Any entry into a HEPA-Vac or PHFS must be consistent with local radiological controls, and normally would be controlled by a radiological work permit. Radiation and contamination surveys should be performed periodically for HEPA-Vacs or PHFS in use and the labels on these units should be updated. The frequency of radiation surveys should depend on the specific use of the unit.

HEPA-Vacs and PHFS tend to be overlooked when it comes to maintenance and testing. Many standards and procedures address maintenance and testing of permanent HVAC HEPA filtration systems. However, for HEPA-Vacs and PHFS, no national standards and procedures are available. To make matters worse, because of their size and portability, personnel assume that they are functioning correctly. Ironically, these units are capable of discharging contamination over large areas of the work site if filter bypass leakage is occurring.

HEPA-Vacs and PHFS tend to be overlooked when it comes to maintenance and testing. Many standards and procedures address maintenance and testing of permanent HVAC HEPA filtration systems. However, for HEPA-Vacs and PHFS, no national standards and procedures are available. To make matters worse, because of their size and portability, personnel assume that they are functioning correctly. Ironically, these units are capable of discharging contamination over large areas of the work site if filter bypass leakage is occurring.

These units by their very nature are prone to leakage. This is mainly because they are small and portable, and thus are transported from workplace to workplace in the back of trucks and are subjected to substantial rough handling by workers. This action creates leaks in units that were previously tested, giving personnel a false sense of security. For this reason, these units should be tested <u>anytime</u> they are moved or transported. When testing these HEPA-Vacs and PHFS, test personnel should apply the same rigorous procedures outlined in ASME N-511[12] and ASME AG-1[3] for the permanent HVAC HEPA filtration systems. After all, HEPA-Vacs and PHFS perform the same functions and have essentially the same components as the permanent HVAC systems.

8.10.3.1 Reasons For Testing HEPA-Vacs or PHFS

- Poor design of the HEPA-Vacs or PHFS
- Poor workmanship and inadequate Quality Control by the HEPA-Vacs or PHFS manufacturer
- Leaks in the filter media itself
- Leaks due to failure of the adhesive bond between the filter media and its frame
- Leaks between the filter frame and cabinet sealing frame seals
- Leaks between the cabinet main frame and the cabinet housing
- Leaks in the cabinet or housing due to damage in transit or handling
- Leaks from misalignment or misassembly of the HEPA-Vacs or PHFS and HEPA filter.
- Leaks resulting from incorrect or inadequate maintenance
- Leaks resulting from improper installation and operation of the HEPA-Vacs or PHFS at the work site

[Note: Many of the above items may not be applicable to units constructed and certified to ASME AG-1[3] criteria.]

8.10.3.2 HEPA Filter Vacuum Cleaner Tests

Numerous suppliers manufacture HEPA-Vacs, and each supplier has several models available. This leads to unique characteristics that must be considered when performing in-place testing. As in the permanent HVAC systems, a thorough visual inspection by trained personnel of the unit to be tested should be performed before conducting the test. This inspection should be done using a checklist tailored to the specific make and model to be tested. These units should also be tested for proper flow and suction capabilities. Generally, a 4- to 6-in.-diameter duct or flex hose 8 to 10 ft long is used to introduce the challenge aerosol to the input of the HEPA-Vacs under test. An upstream probe can be fitted close to the end of the hose for transition to the inlet connector on the unit under test. The output of the aerosol generator should be directed to the other end of this hose. This configuration usually allows adequate aerosol-air mixing of the aerosol challenge.

The greatest challenge to testing HEPA-Vacs is obtaining a representative downstream reading. For most HEPA-Vacs, downstream air is discharged radially in all directions rather than through a duct (as in permanent HVAC systems). To accomplish this, test personnel usually fabricate a collection hood to collect all of the downstream air discharged from the unit under test and connect a duct or hose to the hood. The hose or duct can be fitted with a downstream probe located at least ten diameters downstream of the hood. After the upstream/100 percent point has been established, a downstream reading should be taken with and without the aerosol generator operating. This is done to verify the background reading. Some HEPA-Vacs generate significant amounts of particles due to their design configuration. If a background reading is detected, it should be recorded and deducted from the downstream reading obtained with the aerosol generator operating.

8.10.3.3 PORTABLE FILTRATION SYSTEMS TESTING

There are two basic designs for these systems—those that "pull" air through the HEPA filter and those that "push" air through it. Therefore, some units have the HEPA filter upstream of the motor/blower assembly and others place the HEPA filter downstream of the motor/blower. The advantages and disadvantages of each design concept are summarized in TABLE 8.3 below.

Table 8.3 – Downstream/Upstream HEPA Filter Locations in PHFS

(+) Advantages	(-) Disadvantages
Type A DOWNSTREAM HEPA	Type B UPSTREAM HEPA
(+) easier access to HEPA filter for scanning or leak testing	(-) difficult access to HEPA filter for scanning or leak testing
(+) easier to repair leaks in HEPA filter if allowed	(-) difficult to repair leaks in HEPA filter if allowed
(+) may not require mixing chamber to assure uniform mixing of test aerosol	(-) requires mixing chamber to assure uniform mixing of test aerosol
(-) motor/blower may become contaminated	(+) motor/blower should stay uncontaminated unless filter leaks
(-) cabinet interior may become contaminated	(+) cabinet should stay uncontaminated unless filter leaks

Design, materials, specifications, and quality of construction vary widely among PHFS. These variables have a tremendous impact on overall performance and effectiveness. In particular, the cabinet material must remain rigid and undistorted during shipping, handling, and the rigors of daily operation to prevent the contaminated air from bypassing the HEPA filter. The type and gauge of metal fabrication methods, braces, holes, cracks, fasteners, welds, gaskets, and seals must be designed, specified, and assembled with potential leakage, durability in service, and maintenance in mind.

[Note*:* Much of the above may not be applicable to units constructed and certified to ASME AG-1[3] criteria.]

8.10.4 TESTING PROBLEMS AND SPECIAL CONSIDERATIONS

Some of the designers and manufacturers of negative pressure filtration units have not put much thought or effort into creating units with "integrity testing" in mind. Not only do they unintentionally design-in leaks, but they often overlook the inclusion of features that allow access to areas that are critical for leakage testing. Access to the downstream face of the HEPA filter for the purpose of scanning is virtually impossible in most units where the blower is downstream of the HEPA filter. A mixing chamber with baffles is necessary at the inlet of this type of unit to provide adequate mixing. Downstream measurements of the exhaust air stream can be subject to error due to channeling—the opposite of mixing. The aerosol from a specific leak may simply remain concentrated in a segment of the exhaust air stream. Therefore, sampling must be done at various points across the face of the exhaust air outlet, in effect a "scanning" of the opening. A single-point sample is usually not representative of what is in the exhaust air stream. The same considerations are included in making air velocity measurements across the exhaust opening or duct in accordance with ANSI/ASTM 41-2 (1987)[41]. A single-point reading is not representative.

8.11 REFERENCES

1. ANSI/ASME N510-1980, American National Standards Institute and American Society of Mechanical Engineers, *An American National Standard: Testing of Nuclear Air Cleaning Systems*, New York, 1980.
2. Nuclear Air Cleaning Handbook Draft Revision, 1997.
3. ASME AG-1, American Society of Mechanical Engineers, Current Revision.
4. DOD MIL-STD-282, U.S. Department of Defense Military Standard, Method 102.9.